JC494 U.S. PTO
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PTO/SB/05 (12/97)
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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	19536-706-00 US	*Total Pages*	25
First Named Inventor or Application Identifier			
Mitch Prater			
Express Mail Label No.	EH592703015US		

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents:

ADDRESS TO: **Assistant Commissioner for Patents**
Box Patent Application
Washington, DC 20231

1. [X] Fee Transmittal Form *(Submit an original, and a duplicate for fee processing)*
2. [X] Specification (preferred arrangement set forth below) [Total Pages 10]
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawings (35 USC 113) [Total Sheets 10]
4. Oath or Declaration [Total Pages 2]
   - a. [X] Newly executed (original or copy) (unexecuted)
   - b. [ ] Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 17 completed)* *[Note Box 5 below]*
     - i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b)
5. [ ] Incorporated By Reference (useable if Box 4b is checked) The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [ ] Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
   - a. [ ] Computer Readable Copy
   - b. [ ] Paper Copy (identical to computer copy
   - c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [ ] Assignment Papers (cover sheet & document(s))
9. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
10. [ ] English Translation Document (if applicable)
11. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
12. [ ] Preliminary Amendment
13. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
14. [ ] Small Entity Statement(s) [ ] Statement filed in prior application, Status still proper and desired
15. [ ] Certified Copy of Priority Document (s) *(if foreign priority is claimed)*
16. [X] Other: Declaration (Box 4a.) is unexecuted

17. **If a CONTINUING APPLICATION,** *check appropriate box and supply the requisite information:*

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP)

of prior application No: ____________ / ____________

18. CORRESPONDENCE ADDRESS

[ ] Customer Number or Bar Code Label (Insert Customer No. or Attach Bar code label here) or [X] Correspondence address below

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AB980210.063/19536-706

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09/012574-012398

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FEE TRANSMITTAL

Patent fees are subject to annual revision on October 1. These are the fees effective October 1, 1997. Small Entity payments must be supported by a small entity statement, otherwise large entity fees must be paid. See Forms PTO/SB/09-12.

TOTAL AMOUNT OF PAYMENT ($) 790.00

Complete if Known	
Application Number	Unassigned
Filing Date	Unassigned
First Named Inventor	Mitch Prater
Examiner Name	Unassigned
Group / Art Unit	Unassigned
Attorney Docket No.	19536-706-00 US

METHOD OF PAYMENT (check one)

1. [X] The Commissioner is hereby authorized to charge indicated fees and credit any over payments to:

Deposit Account Number: 13-0257

Deposit Account Name: McCutchen, Doyle, et al.

[X] Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17

[ ] Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance

2. [X] Payment Enclosed:

[X] Check [ ] Money Order [ ] Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	790	201	395	Utility filing fee	$790
106	330	206	165	Design filing fee	
107	540	207	270	Plant filing fee	
108	790	208	395	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 790.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims		-20** =		X		=	
Independent Claims		- 3** =		X		=	
Multiple Dependent						=	

***or number previously paid, if greater; For Reissues, see below*

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	22	203	11	Claims in excess of 20
102	82	202	41	Independent claims in excess of 3
104	270	204	135	Multiple dependent claim, if not paid
109	82	209	41	** Reissue independent claims over original patent
110	22	210	11	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 790.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	400	216	200	Extension for reply within second month	
117	950	217	475	Extension for reply within third month	
118	1,510	218	755	Extension for reply within fourth month	
128	2,060	228	1,030	Extension for reply within fifth month	
119	310	219	155	Notice of Appeal	
120	310	220	155	Filing a brief in support of an appeal	
121	270	221	135	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,320	241	660	Petition to revive - unintentional	
142	1,320	242	660	Utility issue fee (or reissue)	
143	450	243	225	Design issue fee	
144	670	244	335	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	
146	790	246	395	Filing a submission after final rejection (37 CFR 1.129(a))	
149	790	249	395	For each additional invention to be examined (37 CFR 1.129(b))	

Other fee (specify) ____________________

Other fee (specify) ____________________

* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 790.00

SUBMITTED BY

				Complete (if applicable)	
Typed or Printed Name	J. David Hadden			Reg. Number	40,629
Signature	David Hadden	Date	1/23/98	Deposit Account User ID	

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PSEUDO AREA LIGHTS

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January 23, 1998

R.L. Brandes

R.L. Brandes

PSEUDO AREA LIGHTS

FIELD OF THE INVENTION

The invention relates generally to the art of computer graphics and animation. More particularly, the invention relates to efficient approximation of finite light sources using point light sources of varying location and intensity.

BACKGROUND OF THE INVENTION

In order to render a scene in computer graphics or computer animation, computer artists and animators often will place one or more light sources within the scene in order to illuminate it. If, for instance, an animator wished to render a room that was lit by two light bulbs, he or she would construct two light sources, representing the light bulbs, and then calculate the illumination effect of these two sources. The standard construct for such directional light sources is the point source, whereby all light is considered to emanate from a single point.

The point source is the standard construct because calculation of its illumination effect is computationally straightforward. For any given surface point within the scene, the rendering method need only calculate the effect of a single ray of light, which has a singular direction and intensity. The disadvantage of using the point source is its lack of realism. When illuminated by a point source, any surface point in the scene will either be illuminated by the point light source, or else wholly hidden from it. As a result, shadows and other partial lighting conditions are rendered in an unrealistically sharp, binary manner (see Figure 5).

One alternative to using a point light source is to use a finite source, one that has an extended shape and size. The light emerging from a finite source will emanate from its entire surface, and not just a single point. Finite sources illuminate a scene in a much more realistic manner. Some surface points will be illuminated by the entire finite light source, others totally hidden from it. More important is the fact that some points will be <u>partially</u> illuminated by the source.

Despite this superior effect, computer artists and animators do not currently use finite light sources to illuminate their graphics and their scenes. Determination of the total contributing light from a finite light source to a surface point, has, till this point, required a numerical integration over the entire surface of the finite source. Such calculations are simply too cumbersome to be practically used in computer animation. Finite light sources are sometimes used to illuminate single computer-generated scenes or "photos" when a highly realistic image is desired and computational speed is not an issue, but even in these situations the computational burden is considered onerous.

Computer artists and animators run into analogous problems when attempting to simulate ambient light such as skylight. Realistic calculations with respect to simulated ambient light sources are also too cumbersome to make them practical. The conventional technique for simulating ambient light, therefore, is to simply turn up the brightness throughout an entire scene, with perhaps gross modifications for surfaces points that obviously will be differentially affected by the light (such as those under dark shadows). The computation required for this is straightforward, even trivial, but the illumination effect is again not very realistic.

SUMMARY OF THE INVENTION

The invention relates to a method for approximating the illumination effect of a finite light source by a using a point light source of varying intensity and location. These two variables are manipulated depending on the "visibility" of the finite light source from the perspective of the surface point being rendered. The result is realistic illumination with minimal computational effort.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows generally the elements of a computer system suitable for carrying out the present invention.

FIG. 2 shows the main steps involved in rendering a computer-animated scene.

FIG. 3 shows the main steps involved in rendering the surfaces within a computer-animated scene.

FIG. 4 shows the main steps involved in illuminating and shading a rendered surface within a computer-animated scene.

FIG. 5 shows illustrates the problem of unrealistically sharp shadows created by a point light source.

FIG. 6 shows the "terminator region" of partial illumination on an object surface.

FIG. 7 shows the method for choosing a point light source based upon the surface point in question, which results in a particular light vector direction

FIG. 8 shows the method for determining the light intensity based upon the portion of the finite light source which is hidden.

FIG. 9 shows two examples of pseudo-centers used to calculate light vector directions for given points in the terminator region.

FIG. 10 shows the method of determining the light intensity and light vector direction for a given point under an infinite hemisphere of light, based upon the known tangent plane and normal.

DETAILED DESCRIPTION OF TWO EXEMPLARY EMBODIMENTS: FINITE LIGHT SOURCE APPROXIMATION AND INFINITE HEMISPHERE ILLUMINATION

Figure 1 shows a computer system suitable for carrying out the invention. A main bus **1** is connected to one or more CPUs **2** and a main memory **3**. Also connected to the bus are a keyboard **4** and large disk memory **5**. The frame buffer **6** receives output information from the main bus and sends it through another bus **7** to either a CRT or another peripheral which writes the image directly onto film. The computer system is used to approximate the illumination effect of a finite light source and an infinite hemisphere light source. The main steps in carrying out the rendering and illumination of a scene are shown in Figures 2–4.

One exemplary embodiment of the invention involves use of a directional light source for general illumination within a scene. Such a light source might be the only light source within a scene, it might be the primary source (supplemented by secondary light sources) or it might be one of a number of primary light sources (such as a number of simulated light bulbs).

Figure 6 shows a spherical light source illuminating the surface of an object. Spheres are perhaps the most useful shapes to use as light sources because they create an illumination effect similar to that of many real-life directional light sources, such as light bulbs. Computation of their illumination effect, whether by explicit integration or approximation, as in the described invention, is also usually simpler than it is with other shapes. The object to be illuminated is, for illustrative purposes, also shown as a sphere.

With respect to the top of the illuminated object, we can draw two tangents between the light sphere and the object, defining points P_0 and P_1. Points to the right of P_0 are wholly hidden from the light sphere, and thus not illuminated. Points to the left of P_1 are wholly illuminated, which means they receive the total illumination of the light sphere. Calculation of both the light intensity and the light vector direction for these points is straightforward (light intensity being some chosen function and vector direction being the vector between the center of the light sphere, C, and the point P being considered).

The points P_0 and P_1 define a terminator region, within which all points are partially illuminated by the light sphere (note that this terminator region is actually an extended band that circles the sphere, with points analogous to P_0 and P_1 defining its boundaries). N_0 and N_1 are the corresponding normals at those points. Determining the illumination effect by radiosity analysis for each of these points would require a numerically complex integration over the portion of the light sphere that illuminates the points. The described invention approximates these calculations with results that are almost indistinguishable from the numerically complex integration.

Figure 7 shows a tangent plane, Ts, drawn from one of the points P in the terminator region to the light sphere. The tangent plane can be extended further, so that it cuts through the light sphere. Viewed from the side, plane Ts appears as a tangent line (see Figure 7). The portion of the projected disk that is above Ts is above the "horizon line" as seen from point P, and thus considered to shine upon that point. The portion of the light sphere below Ts is below the horizon line, and thus considered hidden from point P.

Comparing Ts with the line drawn from point P to the center of the light sphere, line Ps, it follows that θ, the angle between Ts and Ps, is arccos $(-Ps \cdot N) - \pi/2$ and that D, the distance between the center of the light sphere and the line Ts, is tan (θ) x Ps. The vector direction of the light from the truncated sphere to the object can be approximated by creating a "pseudo-center" X with respect to the light sphere. Pseudo-center X is determined by shifting the center of the light sphere, C, a distance D in the direction given by the vector Ps x (N x Ps). The vector from this newly defined X to point P defines the vector direction of light used to illuminate point P (see Figure 7).

The intensity of light reaching the point P will depend on the area of the projection of the truncated light source on a plane perpendicular to the line Ps. That area can in turn be approximated by the area of the truncated sphere projected onto the plane perpendicular to the tangent plane Ts containing the line Ps which is the projection shown in Figures 7 and 8. The intensity of the constructed point source at X that is used to illuminate point P in the terminator region is thus calculated as a function of the portion of the light sphere that is above

the horizon, which is also determined from D. We can see in Figure 8 that the areas of the light sphere visible from point P are areas Z, A and A'. Area Z is simply one-half the area of the disk. Area A is the sum of areas F and G, and the area of A' = A. The area of F is $D(R^2-D^2)^{1/2}/2$ and the area of G is $[R^2\arcsin(D/R)]/2$. These trigonometric calculations can in practice be approximated by the function $T^2(3-2T)$, where T is defined as $(D+R)/2R$.

The described invention thus uses a point light source of varying location and intensity to approximate the effect of a finite light source. Figure 9 shows the pseudo-center X, standing alone as a point source, in order to illuminate point P. Figure 9 also shows another pseudo-center X' derived by the same method and used to illuminate point P'. The invention achieves an illumination effect similar to that of true radiosity analysis at a computational cost comparable to that required for a point source.

Note that in this embodiment of the invention, the vector direction of the light is drawn from the pseudo-center X, and not from some pseudo-<u>surface</u> point at a given radius as one might expect. This simplification helps reduce the computational load. When the radius of the finite light source is small compared to the distance between the source and the surface it illuminates, the simplification does not diminish the realism of the effect.

A second exemplary embodiment of the invention is used to simulate ambient light such as skylight. This embodiment first requires the construction of a lighted hemisphere of infinite radius within a scene. The illumination effect of the hemisphere is then approximated using point sources of varying location to achieve a realistic light effect.

In Figure 10, we can see the lighted hemisphere that encloses the animated scene like a dome, as well as a point P within that scene. To determine the intensity of ambient light that shines upon that point, we first derive the tangent plane and the normal vector, N, to that point (usually from the function that is used to draw P). If we extend this tangent plane so that it reaches out to infinity and intersects the hemisphere, we can see that only a portion of the hemisphere can actually shine light upon point P. That fraction is $1-\arccos(N \cdot L)$, where L is a vector that points toward a chosen "pole" of the hemisphere. The intensity is a simple (usually direct) function of that portion.

The vector direction of light shining upon point P is determined by using the centroid of that portion of the hemisphere cut by the tangent plane. In Figure 10, we see the centroid O, which is determined by the vector addition of N and L. This centroid then acts a point light source with respect to point P. The vector from O to P defines the vector direction of light. The infinite radius of the light hemisphere serves as a fiction to determine the position of the point O.

The specific arrangements and methods described herein are merely illustrative of the principles of the present invention. Numerous modifications in form and detail may be made by those of ordinary skill in the art without departing from the scope of the present invention. Although this invention has been shown in relation to particular embodiments, it should not be considered so limited. Rather, the present invention is limited only by the scope of the appended claims.

CLAIMS

What is claimed is:

1. A method for illuminating surfaces in computer graphics comprising the steps of:

constructing one or more finite light sources within a computer animated scene, each of the finite light sources having a finite size and a center;

constructing a plurality of surfaces with the scene, each surface consisting of a plurality of points; and

approximation of the illumination effect of each of the finite light sources by the use of a plurality of point light sources of varying intensity.

2. The method of claim 1 wherein a portion of each of the light sources illuminates each of the points.

3. The method of claim 2 comprising the further step of approximately calculating a light intensity and a light vector direction as a function of the portion of each of the light sources which illuminates each of the points.

4. The method of claim 3 comprising the further step of calculating the light intensity as a function of the portion of the light source which illuminates each of the points.

5. The method of claim 4 comprising the further step of approximating the light vector direction as a function of the portion of the light source shines upon the point.

6. The method of claim 1 wherein said finite light source is a sphere.

7. A method for illuminating surfaces in computer graphics comprising the steps of:

constructing a hemispherical light source of infinite radius;

constructing a plurality of surfaces with said scene, said surfaces consisting of a plurality of points.

approximation of the illumination effect of each of the hemispherical light source by the use of a plurality of point light sources.

8. The method of claim 7, comprising the further step of calculating a light intensity and a light vector direction as a function of a portion of the light source which illuminates each of the points.

9. The method of claim 8 wherein said light vector direction is a function of the portion of said hemispherical light source which shines upon said point.

10. The method of claim 9 wherein said light intensity is a function of the portion of said hemispherical light source which shines upon said point.

ABSTRACT

Computer animators have, till now, largely relegated themselves to using point light sources when simulating directional light sources in computer graphics and animation. The illumination achieved is computationally feasible but not totally realistic. While it is possible to use a finite light source of given size and shape to achieve a more realistic effect, the radiosity analysis required to calculate the illumination effect of such a light source is so cumbersome that it cannot be used for real-time computer animation. The described invention allows the animator to approximate the illumination effect of a finite light source by using a point source of varying location and intensity. Another embodiment of the invention allows the animator to realistically simulate ambient light by a similar method. The resulting illumination effects are comparable to those achieved with full radiosity analyses at much lower computational loads.

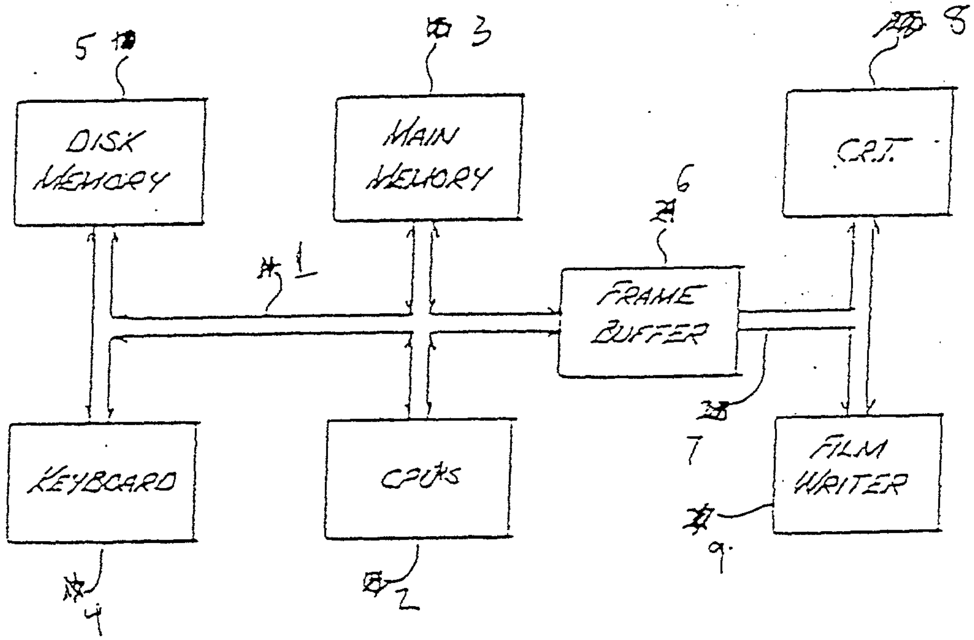
5
DISK MEMORY
3
MAIN MEMORY
8
C.R.T.
1
6
FRAME BUFFER
7
KEYBOARD
CPU's
FILM WRITER
9
4
2

FIG. 1

Rendering Process

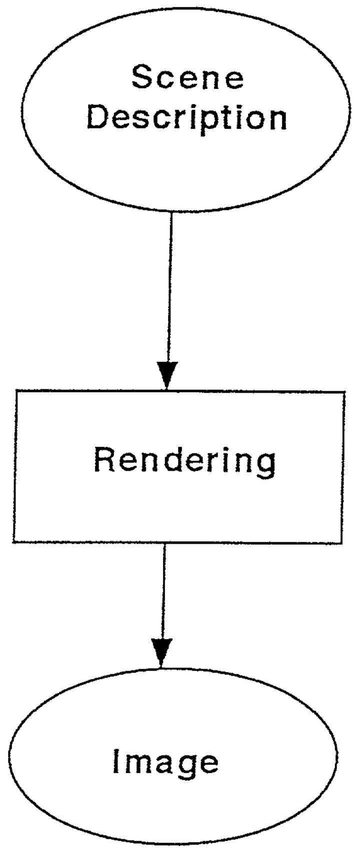

FIG. 2

Rendering

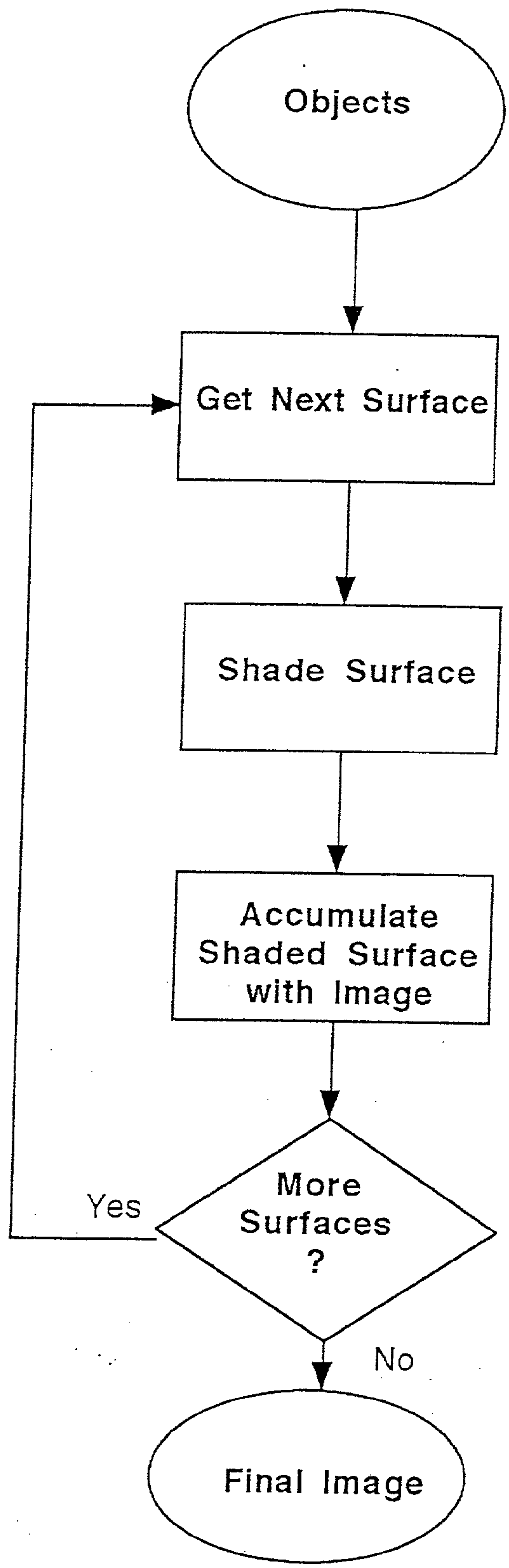

FIG. 3

Shade Surface

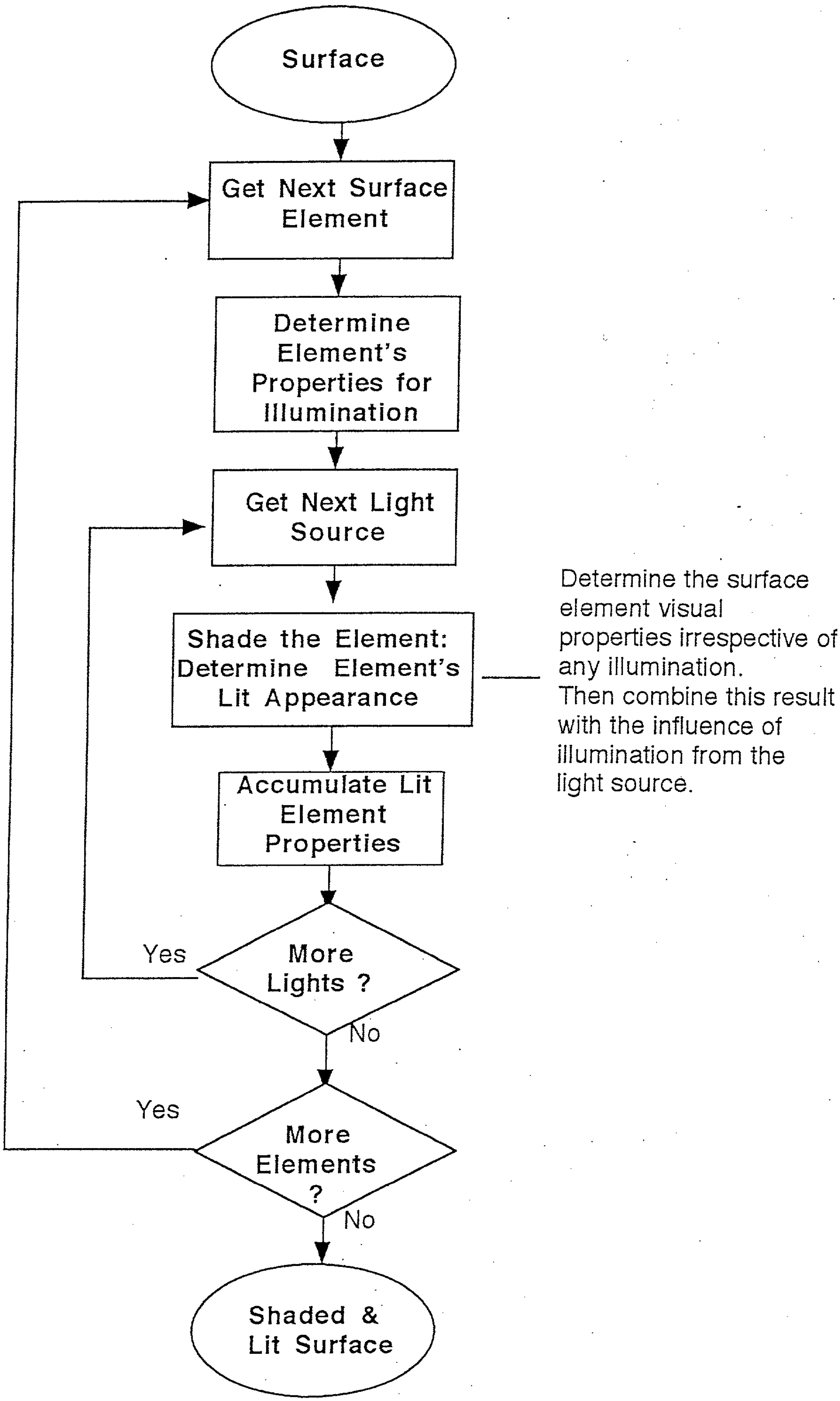

FIG. 4

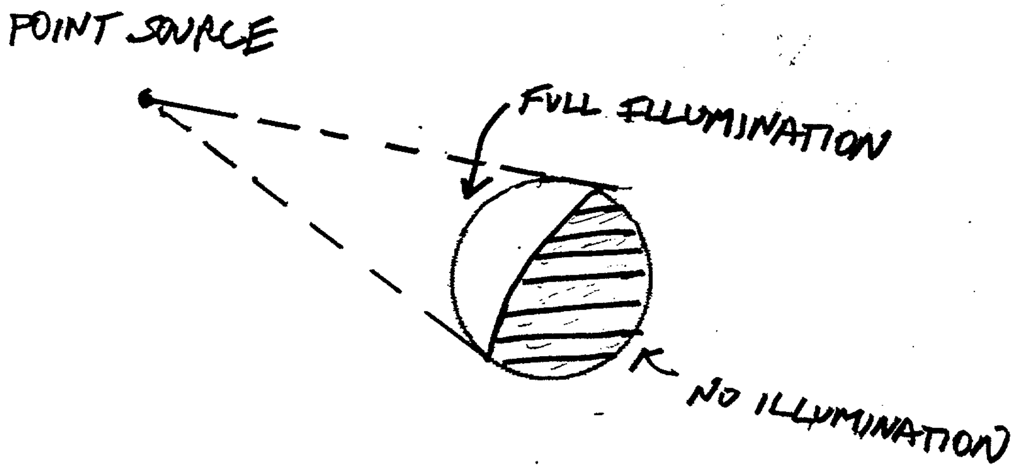

FIG. 5

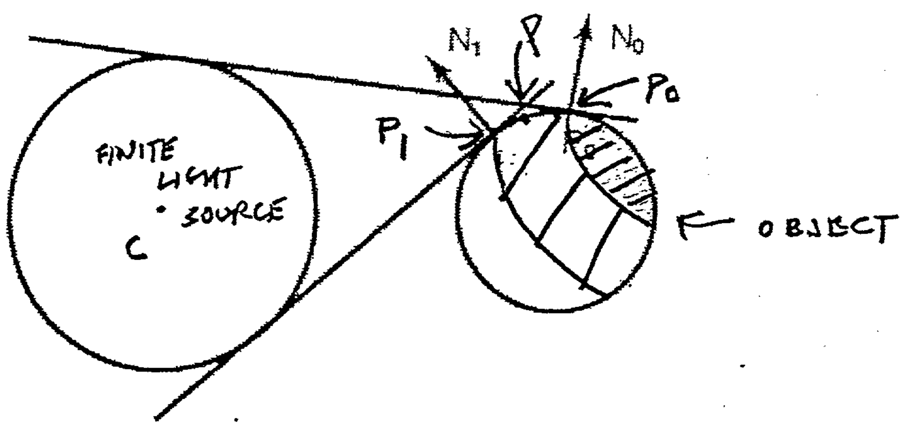

FIG. 6

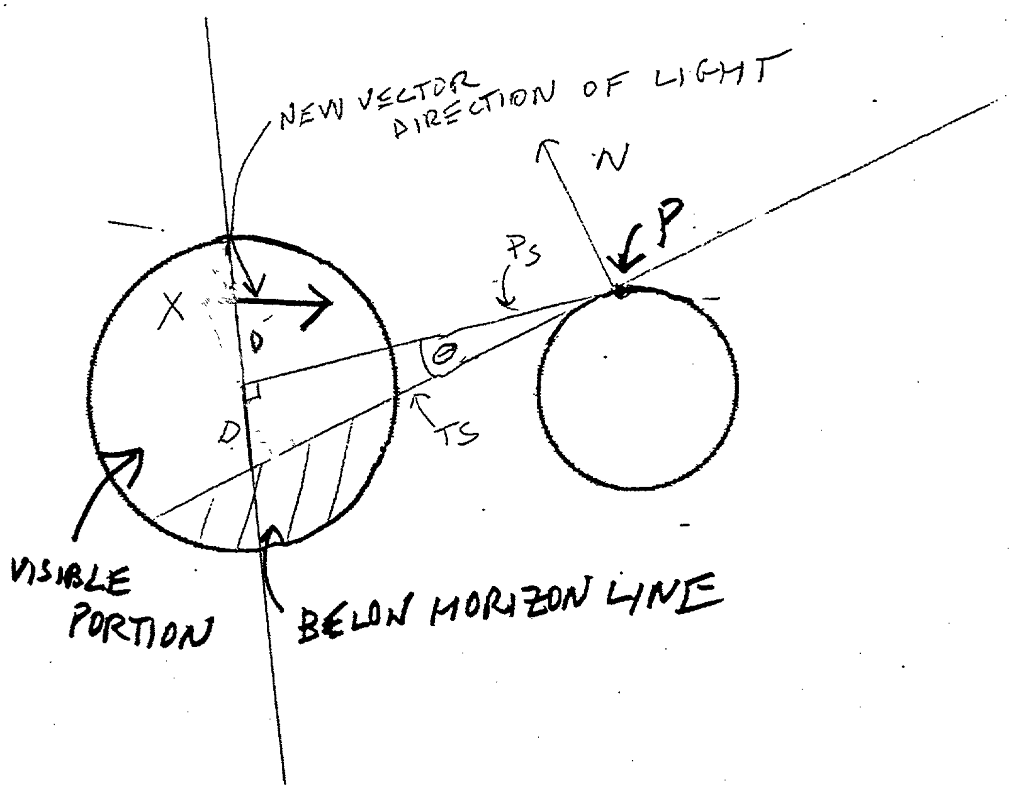
NEW VECTOR
DIRECTION OF LIGHT
N
P
Ps
X
θ
D
TS
VISIBLE
PORTION
BELOW HORIZON LINE

FIG. 7

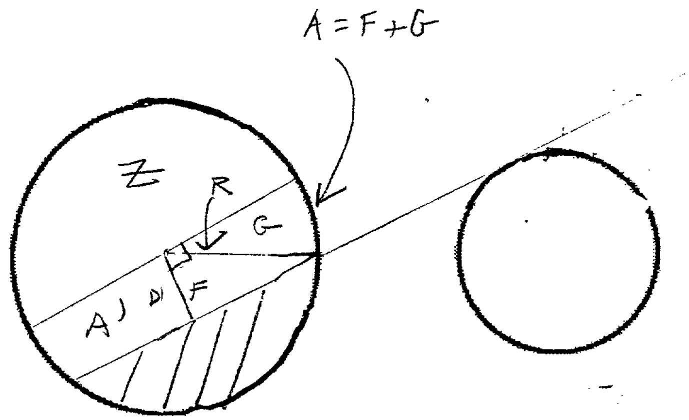

FIG. 8

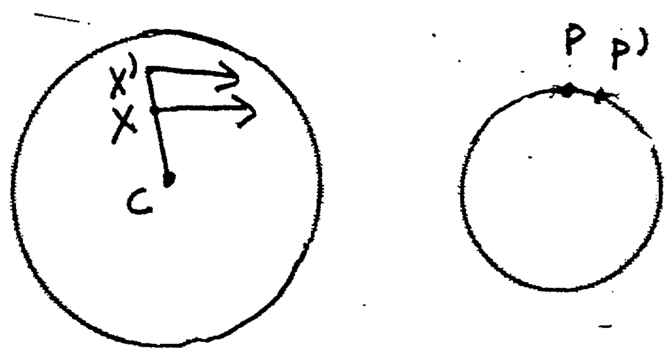

FIG. 9

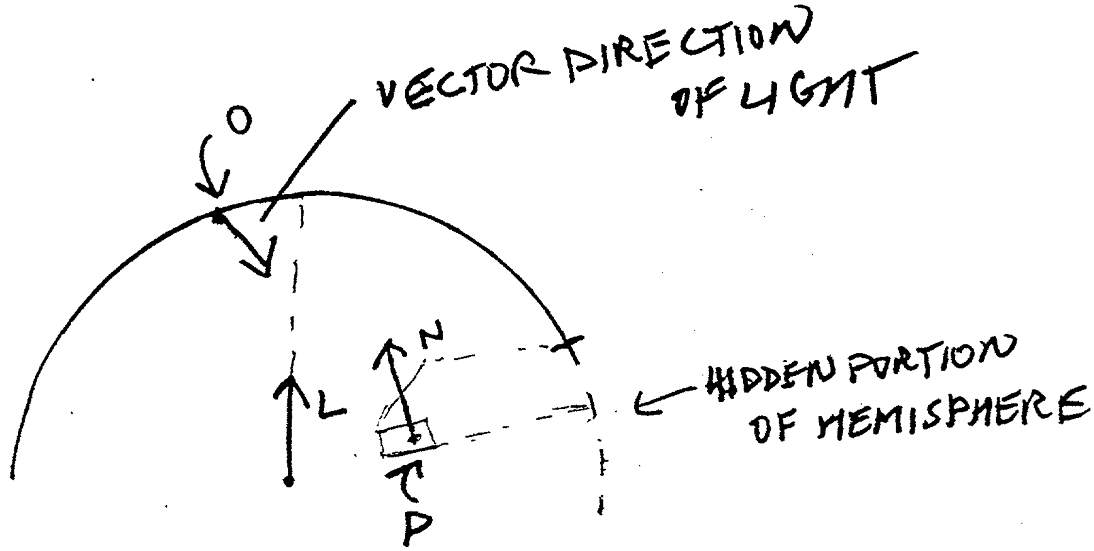
O
VECTOR DIRECTION OF LIGHT
N
L
P
HIDDEN PORTION OF HEMISPHERE

FIG. 10

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As below named inventor, I hereby declare that:

My residence address and citizenship is as stated below next my name.

I believe I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled: PSEUDO AREA LIGHTS, the specification of which

_X_ is attached hereto.

____ was filed on [date] as
Application Serial Number [ ]
and was amended on [date].

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate, listed below and so identified, and I have also identified below any foreign application for patent or inventor's certificate on this invention filed by me or my legal representatives or assigns and having a filing date before that of the application on which priority is claimed.

Number	Country	Day/Month/ Year Filed	Priority Claimed - Yes or No

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

Application Serial No.	Filing Date	Status

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorneys, with full power of substitution and revocation, to prosecute this application and to transact all business in the United States Patent and Trademark Office connected therewith and request that all correspondence and telephone calls in respect to this application be directed to McCUTCHEN, DOYLE, BROWN & ENERSEN, Three Embarcadero Center, San Francisco, California 94111, Telephone No. (415) 393-2000:

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William W. Chuang	39,635
Nina K. Srejovic	40,342
Andrew Kumamoto	40,690
Joseph Yang	41,387
Michael Shuster	41,310
J. David Hadden	40,629
William E. Thomson	20,719

Full name of first
and sole inventor: Mitch Prater

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